PROCESS FOR SEQUENTIALLY APPLYING SAGD TO ADJACENT SECTIONS OF A PETROLEUM RESERVOIR

FIELD OF THE INVENTION

This invention relates to recovering heavy oil from an underground reservoir using a staged process involving, in the first stage, steam assisted gravity drainage, and in the second stage, non-condensible gas injection and reservoir pressurization.

BACKGROUND OF THE INVENTION

Steam assisted gravity drainage ("SAGD") is a process first proposed by R. M. Butler and later developed and tested at the Underground Test Facility ("UTF") of the Alberta Oil Sands Technology and Research Authority ("AOSTRA"). The SAGD process was originally developed for use in heavy oil or bitumen containing reservoirs, (hereinafter collectively referred to as 'heavy oil reservoirs'), such as the Athabasca oil sands. The process, as practised at the UTF, involved:

- Drilling a pair of horizontal wells close to the base of the reservoir containing the heavy oil. One well was directly above the other in relatively close, co-extensive, spaced apart, parallel relationship. The wells were spaced apart 5 – 7 meters and extended in parallel horizontal relationship through several hundred meters of the oil pay or reservoir;

- Then establishing fluid communication between the wells so that fluid could move through the span of formation between them. This was done by circulating steam through each of the wells to produce a pair of "hot fingers". The span between the wells warmed by conduction until the contained oil was sufficiently heated so that it could be driven by steam pressure from one well to the other. The viscous oil in the span was replaced with steam and the wells were then ready for production;
- Then converting to SAGD production. More particularly, the upper well was used to inject steam and the lower well was used to produce a product mixture of heated oil and condensed water. The production well was operated under steam trap control. That is, the production well was throttled to maintain the production temperature below the saturated steam temperature corresponding to the production pressure. Otherwise stated, the fluids being produced at the production interval should be at undersaturated or "subcooled" condition. (Subcool = steam temperature corresponding to the measured producing production pressure – measured temperature.) This was done to ensure a column of liquid over the production well, to minimize "short-circuiting" by injected steam into the production well. The injected steam began to form an upwardly enlarging steam chamber in the reservoir. The chamber extended along the length of the horizontal portions of the well pair. Oil that had originally filled the chamber sand was heated, to mobilize it, and

drained, along with condensed water, down to the production well, through which they were removed. The chamber was thus filled with steam and was permeable to liquid flow. Newly injected steam moved through the chamber and supplied heat to its peripheral surface, thereby enlarging the chamber upwardly and outwardly as the oil was mobilized and drained together with the condensed water down to the production well.

This process is described in greater detail in Canadian patent 1,304,287 (Edmunds, Haston and Cordell).

The process was shown to be commercially viable and is now being tested by several oil companies in a significant number of pilot projects.

Now, the operation of a single pair of wells practising SAGD has a finite life. When the upwardly enlarging steam chamber reaches the overlying, cold overburden, it can no longer expand upwardly and heat begins to be lost to the overburden. If two well pairs are being operated side by side, their laterally expanding chambers will eventually contact along their side edges and further oil-producing lateral expansion comes to a halt as well. As a result, oil production rate begins to drop off. As a consequence of these two occurrences, the steam/oil ratio ("SOR") begins to rise and continued SAGD operation with the pair eventually becomes uneconomic.

If one considers two side-by-side SAGD well pairs which have been produced to "maturity", as just described, it will be found that a ridge of unheated oil is left between the well pairs. It is of course desirable to minimize this loss of unrecovered oil.

In Canadian patent 2,015,460 (Kisman), assigned to the present assignee, there is described a technique for limiting the escape of steam into a thief zone. For example, if steam is being injected into a relatively undepleted reservoir section and there is a nearby more depleted reservoir section, forming a low pressure sink, there is a likelihood that pressurized steam will migrate from the undepleted section into the more depleted section – which is an undesired result. One wants to confine the steam to the relatively undepleted section where there is lots of oil to be heated, mobilized and produced. The Kisman patent teaches injecting a non-condensible gas, such as natural gas, into the more depleted section to raise its pressure and equalize it with the pressure in the relatively undepleted section. By this means, the loss of steam from the one section to the other can be curtailed or minimized.

The Kisman patent further teaches that pressurizing the more depleted section with natural gas has been characterized by an increase in production rate from that section, if the production well penetrating the section is produced during pressurization.

SUMMARY OF THE INVENTION

In accordance with the present invention, a novel process is provided for producing adjacent sections of an underground reservoir containing heavy oil. Each section is penetrated by one or more wells completed for SAGD operation, preferably one or more pairs of horizontal injection and production wells. The process comprises:

(a) injecting steam into the first section of the reservoir to practice SAGD and produce contained oil, until the steam/oil ratio rises sufficiently so that further production by SAGD from the section is substantially uneconomic;

(b) then reducing or terminating steam injection into the first section and injecting non-condensible gas into the section to maintain it pressurized;

(c) continuing to produce oil from the first section while it is pressurized; and

(d) concurrently with step (c), injecting steam into the adjacent second section to practice SAGD therein and produce contained oil;

(e) while preferably maintaining the first section pressurized to substantially the same pressure as exists in the second section during step (d).

Steps (b) and (c) constitute a post-steam wind-down of oil production from the first section. Over time, oil production rate will drop off during wind-down and eventually it will again become uneconomic to justify continuing to produce the first section. However it may still be desirable to continue maintaining pressurization in the first section to limit steam loss from the second section.

The process provides a strategy for sequentially producing adjacent sections across the reservoir. It takes advantage of gas pressurization to prevent steam leakage from a less depleted section undergoing SAGD to a mature, more depleted section. It also maximizes production from each section by subjecting it to sequential SAGD and pressurization production stages.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In accordance with the best mode of the process known to the applicants, it comprises:

(a) directionally drilling one or more pairs of wells from ground surface into a reservoir first section, to provide generally parallel, horizontal, co-extensive, spaced apart, upper and lower well portions extending through the section, and completing the wells for SAGD production;

(b) establishing fluid communication between the injection and production wells of each pair, for example by circulating steam through both wells, to heat the span between the wells by heat conduction, and then displacing and draining the oil in the span by injecting steam through the upper injection well and opening the lower production well for production;

(c) practising SAGD in the reservoir first section by injecting steam through the injection wells and producing the produced heated oil and condensed water through the production wells while operating said production wells under steam trap control;

(d) preparing a second adjoining section of the reservoir for SAGD production by carrying out the provision of wells and establishing fluid communication between the wells of each pair as in steps (a) and (b);

(e) terminating or reducing steam injection into the reservoir first section injection wells and initiating natural gas injection through said injection wells to increase the pressure in the reservoir first section to about the anticipated steam injection pressure in the reservoir second section and maintaining the pressure at about this level while simultaneously producing residual heated oil and steam condensate through the production wells under steam trap control; and

(f) concurrently with step (e), practising SAGD in the reservoir second section.

In connection with practising steam trap control with wells extending down from ground surface and having riser and horizontal production sections, it is preferred to operate as follows:

- measuring the downhole temperature at the injection and production wells of an operating pair, using thermocouples;

- establishing the temperature differential between the two wells and throttling the production well to maintain the differential at a generally constant value (say 7°);
- monitoring for significant surges in vapour production rate at the ground surface production separator and for surges in steam injection rate; and
- adjusting throttling to minimize the surges.

Otherwise stated, a generally constant liquid rate at the wellhead is maintained and the bottomhole production temperature is allowed to vary within a limited range.

The invention is characterized by the following advantages:

- additional oil is recovered from the mature wells during the gas pressurization stage, while simultaneously reducing steam leakage from the second reservoir section;
- use is made of the residual heat left in the mature reservoir section; and
- a finite steam-producing plant can be applied in sequence to a plurality of adjacent sections of the reservoir, without severe steam loss from a section undergoing SAGD to an adjacent depleted section.